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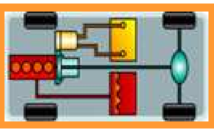
- Overview of DC ZEV Activities -

ZEV Technology Symposium
September 26, 2006
Sacramento, CA

DaimlerChrysler Advanced Technology Programs

Fuel Cell Vehicles

Hybrid Electric Vehicle



Battery Electric Vehicle

Advanced Powertrains

Enabling Technologies

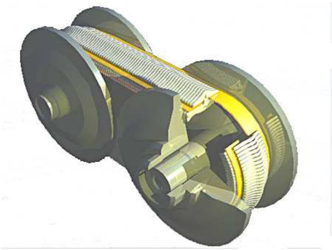
Advanced Powertrains

World Engine

- Inline 4 cylinder - three displacements
- Dual-cam Variable Valve Timing (VVT)
- Four valves per cylinder
- Dual overhead camshafts

- Electronic Throttle Control (ETC)
- High compression
- Manifold flow control valves

Continuously Variable Transmission (CVT)



- Offers improved driveability, fuel economy and performance.
- Allows engine to operate at optimum combination of speed and throttle opening and fuel economy for power requirement.
- Provides a wide ratio (6.0-to-1) spread of gears from first gear to overdrive for best performance over all vehicle speeds.

GEM Neighborhood Electric Vehicle

- Zero emissions
  - ZEV mandate success story
- Conventional vehicle substitution
  - Eliminates cold starts (emissions reduction)
  - Reduces ICE vehicle miles traveled (congestion mitigation)
  - Reduces petroleum consumption
- Congestion mitigation
  - As part of transportation system toolbox reduces VMT
  - For day-to-day travel; smaller than conventional vehicles

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Hybrid Electric Vehicle

Joining Forces

- Sets standards with a family of products
- Increases technical expertise
- Shares elements of cost, risk, and benefits
- Pools volume leading to economies of scale
- “Leap frog” existing technology


washingtonpost.com

BMW joins DaimlerChrysler/GM hybrid project

By Michael Shields, European Automotive Correspondent

Reuters

Wednesday, September 7, 2005; 9:04 AM

sueddeutsche.de

BMW schließt sich Hybrid-Allianz von GM und DaimlerChrysler an

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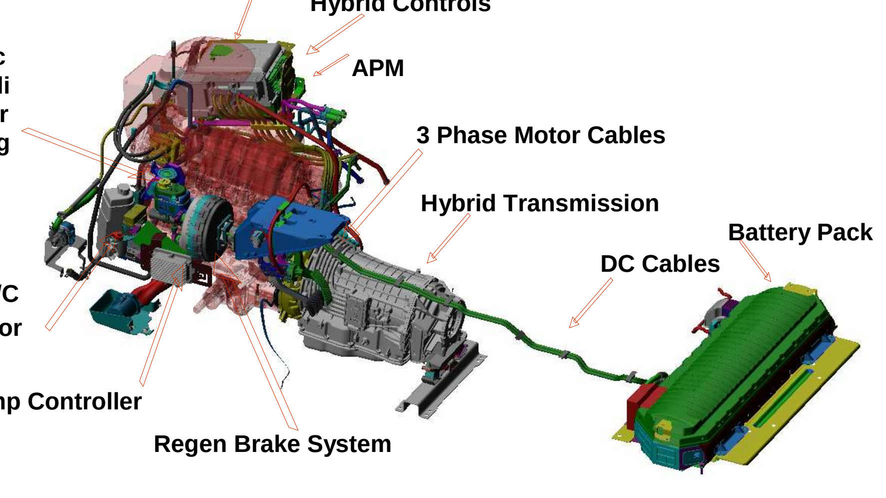
2-Mode Hybrid Technology Application

Improvements over the current 5.7 L to optimize performance and fuel economy:

- **Variable Cam Timing (Atkinson cycle capable)**
- **Increased MDS Operation**
- **EGR (Exhaust Gas Recirculation)**
- **Rapid Heat up cooling system**
- **Compression ratio increase (under investigation)**

"Delivering significant fuel economy – up to 25-percent improvement – the advanced two-mode full hybrid system will provide great performance in a wide range of applications."

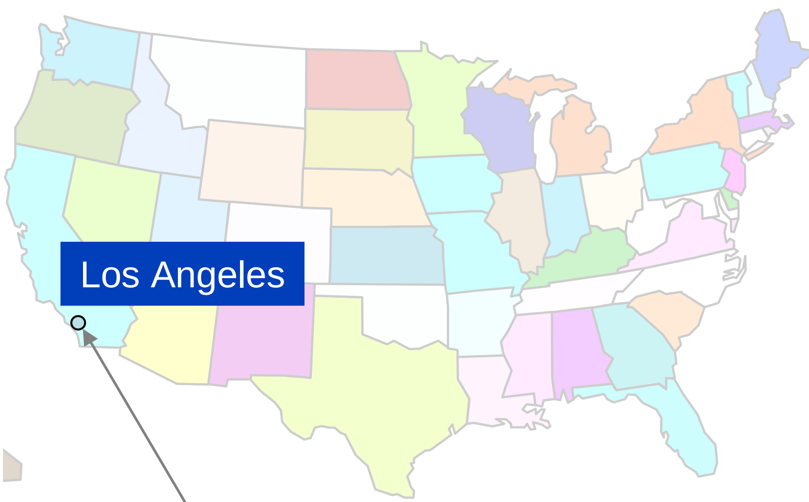
Retains vehicle utility



Sprinter PHEV – Proof of Concept

Partner with the Electric Power Research Institute (EPRI)

Project Decision in 2003 with Two Vehicles



- Cargo Van
- 8,550 lbs
- 140 inches
- Gasoline

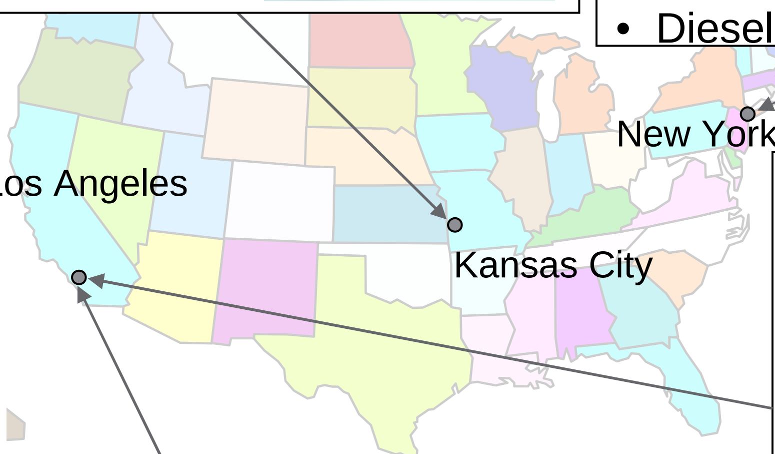
	California 1 (SCE)	California 2 (AQMD)
Basic Vehicle	Panel Van	
Engine	4-Cyl Gasoline (105 KW/215 Nm)	
Transmission	Automatic	
Weight	2.025 kg	
Payload	1.475 kg	
Axles	4.875	
E- Motor Power/Torque (Peak)	70 kW (90 kW) / 130-180 Nm (275 Nm)	
Battery Type	NiMH	Li-Ion
Battery Capacity	14 kWh	14.4 kWh
Battery Weight	350 kg	160 kg
Fuel/CO2 – Reduction	Between 10% and 50% depending on opperation	
All-Electric Range	20 miles	
Payload	1000 kg	1200 kg

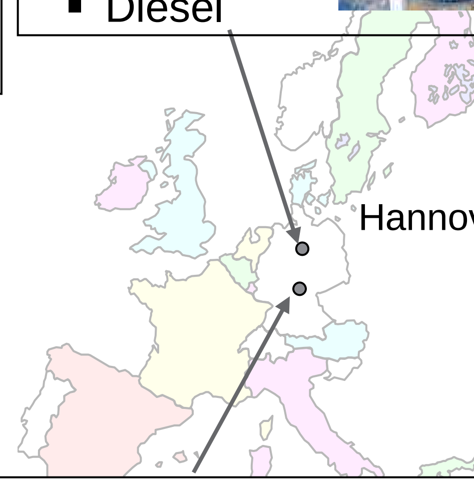
Total of Six Prototype Sprinter PHEVs

6th vehicle
- Cargo Van
- 8,550 lbs
- 140 inches
- Diesel

5th vehicle
- Cargo Van with bus body
- 8,550 lbs
- 158 inches
- Diesel

1st IAA
- 8,550 lbs
- 140 inches
- Diesel





4th vehicle
- Cargo Van
- 8,550 lbs
- 140 inches
- Gasoline

3rd vehicle
- Cargo Van
- 8,550 lbs
- 140 inches
- Gasoline

2nd vehicle
- KaWa
- 3.5t
- 140 inches
- Diesel

Vehicle Characteristics

- Overview -

	ZF Sachs	Development Vehicle (1AA)	FedEx/NY Times	Kansas City
Basic Vehicle	Panel Van			Panel Van/Para Transit Bus
Engine	Diesel 80 kW/270 Nm		Diesel 115 kW/330 Nm	
Transmission	Automatic W5A380			
Weight	2,025/2,055 kg			
Payload	1,475/1,445 kg			
Axles	4.857 / 3.727			
E-Motor Power/Torque (Peak)	70 kW (90 kW) / 130-180 Nm (275Nm)			
Battery Type	NiMH	Li-Ion		
Battery Capacity	14 kW	14.4 kW		
Battery Weight				
Fuel/CO_2 – Reduction	Between 10% and 50% depending on opperation			
All-Electric Range	20 miles			
Payload	1200 kg			

Phase 2 - Technical and Market Feasibility Study

- 18 more field evaluation vehicles in the US planned after completion of Phase I
  - Customers (among others):
    - Large Fleets
    - Utility Companies
    - Transit Authorities

Vehicle Specifications

Gasoline hybrid alternatives

- 6-Cylinder Gasoline (NAFTA)
  - NAFTA cert, NGV3
  - MCG engine for NAFTA

Diesel hybrid alternatives

- 4-Cylinder Diesel (Germany)
  - Europe cert, NGV3
  - Experience for successor

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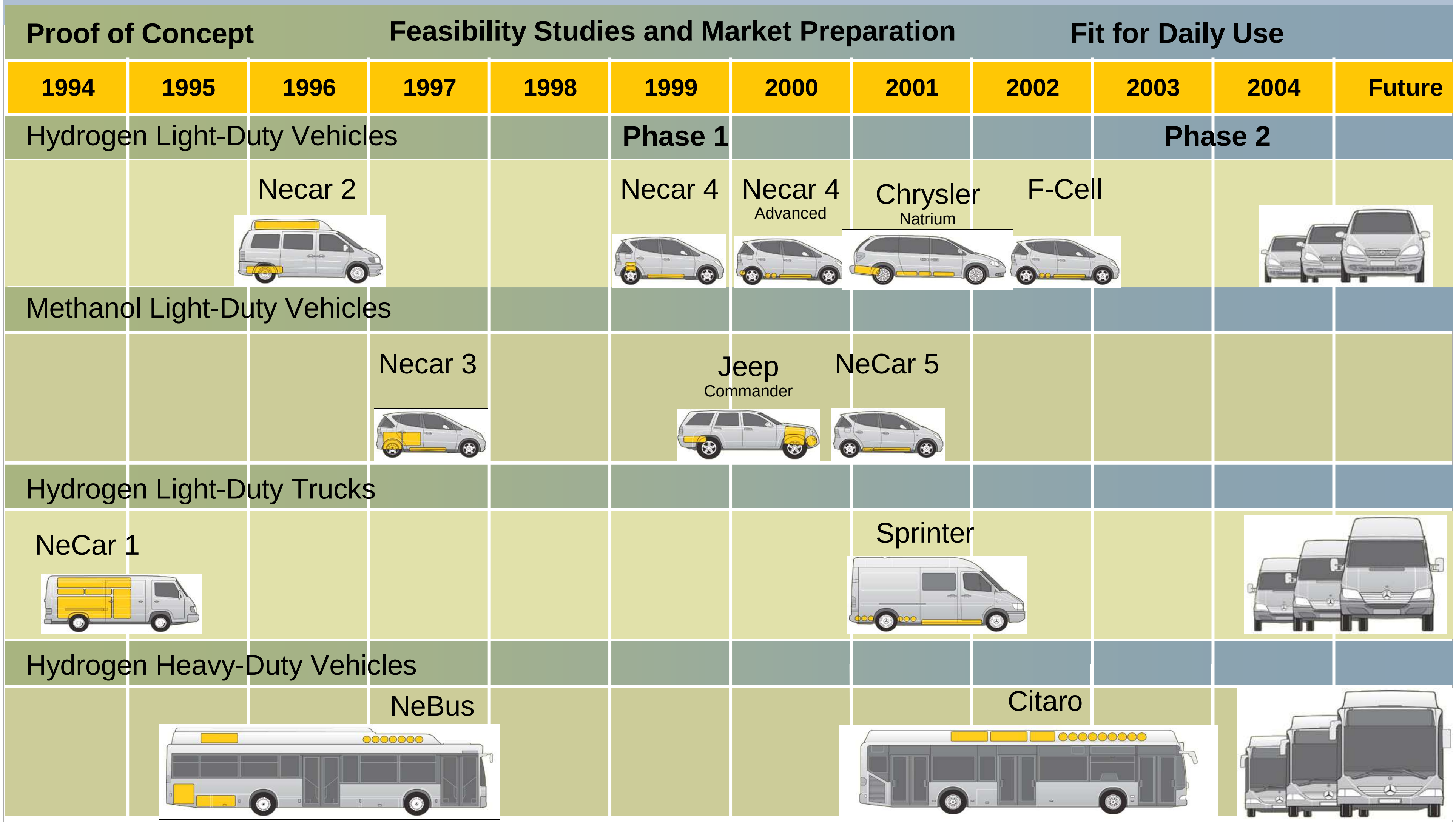
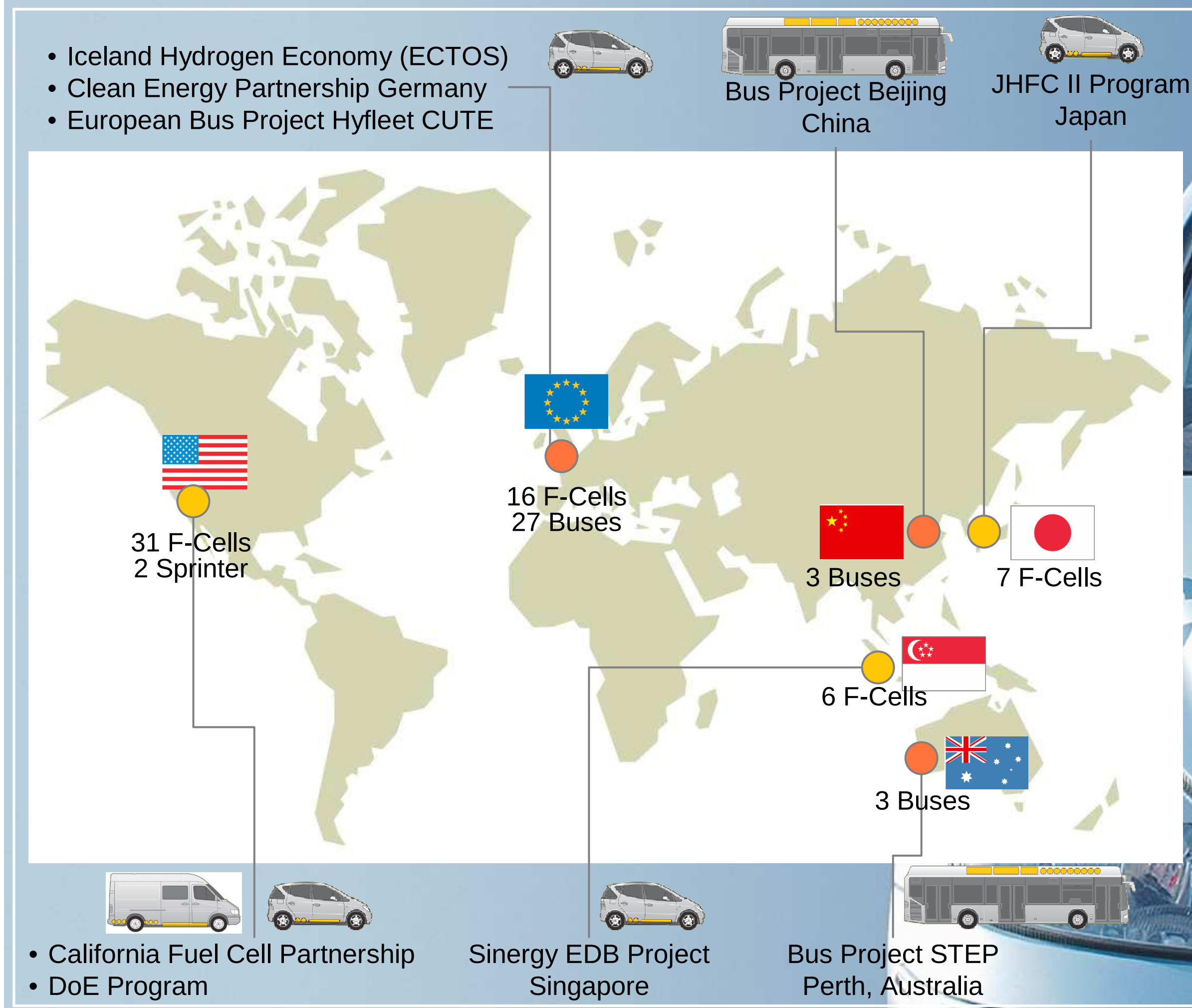
Timeline of DaimlerChrysler Fuel Cell Vehicles



Preparing the Market
Worldwide Fleet Operations and Customers



Customer Feedback

- Good reliability
- No switching of gears
- Low noise
- Good dynamic reaction
- Low range
- Few fueling stations

USA

Japan

Germany

Singapore

Worldwide leading Experiences with DaimlerChrysler Fuel Cell Vehicles

60 F-Cell vehicles in customer hands (since 2004)	36 Buses (Citaro) Europe, Australia, China	3 Sprinters at UPS Europe, USA
		
~ 495.000 miles*	~ 837.000 miles*	~ 37.000 miles*

- DaimlerChrysler as pioneer of Fuel Cell Vehicle
- Daily operation of more than 100 FCV's all over the world
- Long experience with FCV's (first FCV in 1994)
- Broad portfolio of FCV's: passenger cars, buses, vans
- Operation of FCV's by customers in different climate zones with varying ambient temperatures

Basis for technology validation and market development (customer acceptance, infrastructure build-up, C&S)

*Data June 2006

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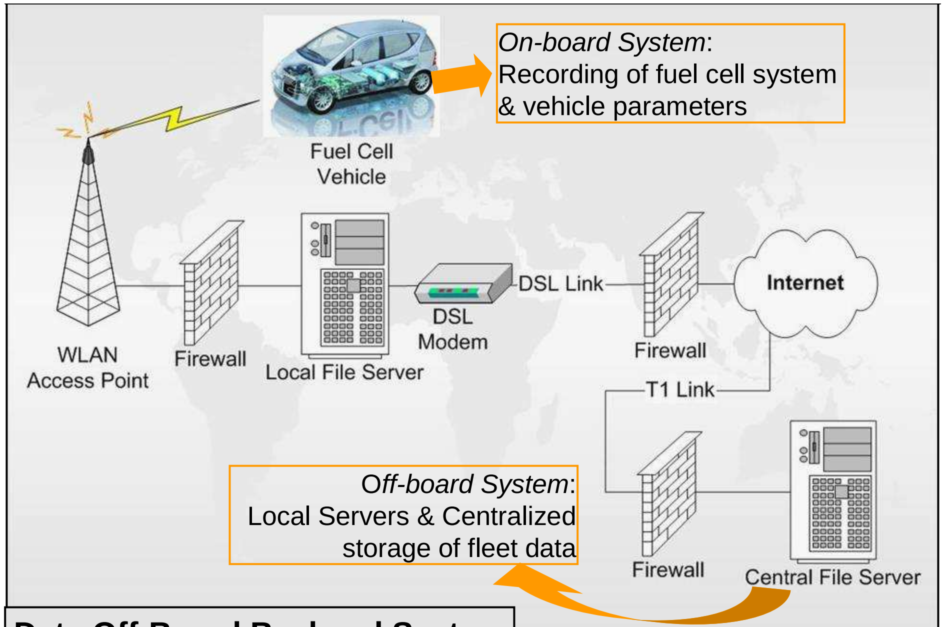
Data Collection: Fleet Data Acquisition System

What is the FDA system and its use for DC

The fleet data acquisition system enables DC to collect operational data from all Fuel Cell vehicles worldwide. The data is collected on one central server.

No competitor has a comparable comprehensive data collection system, which allows DC to build up considerable know-how on vehicle operations with customers in daily use.



Data Off-Board Backend System

On-board Functionality

- Integrated with existing navigation unit
- Powerflow display
- Technician displays

Off-board Functionality

- Automated Data Analysis
- Drive Reports
- Data Mining

FDA is basis for:

- Feedback to R&D (prioritization, lessons learned for next Generation)
- Fleet performance

Fuel Cell Technology Roadmap

Bus

Generation 1
Technology Demonstration

Generation 2
Customer Acceptance

Future Generations

Passenger Cars
Lead Application

2004 — **Generation 1**
Technology Demonstration
F-Cell

2009 — **Generation 2**
Customer Acceptance
B-Class F-Cell

2012 — **Generation 3**
Cost Reduction I

2015 — **Generation 4**
Market Introduction
Cost Reduction II

2020 — **Generation 5**
Mass Production

Sprinter

Generation 1
Technology Demonstration

Generation 2
Customer Acceptance

Future Generations

DaimlerChrysler is dedicated to commercialize Fuel Cell Vehicles

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Generation 1 (Technology Demonstration)
F-Cell, 2004

Specifications F-Cell:	
Vehicle type	Mercedes-Benz A-Class (extended version)
Fuel cell system	PEM - 72 kW (97 hp)
Drive	Electric motor Power (Continuous / Peak): 45 kW / 65 kW (87hp) Max. torque: 210 Nm (156 ft.-lb.)
Fuel	Compressed Hydrogen (350 bar / 5,000 psi)
Range	177 km (110 miles)
Max Speed	140 km/h (87 mph)
Battery	NiMh, air-cooled, Power (Continuous / Peak): 15 kW **/** 20 kW (27hp); Capacity: 6.0 Ah, 1.2 kWh

1994 - 2004: Achievements

- High efficiency
- Zero/ultra low emissions
- Low noise
- High driving comfort
- Performance, package & weight
- Use of alternative fuels
- New innovative vehicle concept
- Basic demonstration of customer benefits

Significant improvements within 10 years

Generation 2 (Customer Acceptance)
B-Class F-Cell, as of 2010

Specifications B-Class F-Cell:	
Vehicle type	Mercedes-Benz B-Class
Fuel Cell System	PEM, 80 kW (90kW)
Drive	IPT Power (Continuous / Peak): 70 kW/100 kW (136hp) Max. torque: 320 Nm
Fuel	Compressed Hydrogen (700 bar / 10,000 psi)
Range	400 km (250 miles)
Max Speed	170 km/h (106 mph)
Battery	Li-Ion (Mn), Power (Continuous / Peak): 24 kW **/** 30 kW (40hp); Capacity: 6.8 Ah, 1.4 kWh

2005 - Future: Challenges
- Weight
- Reliability and lifetime
- Hydrogen storage
- Freeze start
- Cooling
- Policy framework & financial planning
- Cost

B-Class
- Higher stack lifetime of 2000h
- Increasing of power (65kW⇨100kW)
- Higher reliability
- Longer range (160km⇨400km)
- Freeze start ability below 0℃
- Li-Ion battery
- Decrease component costs




Outlook on Mass Production F600 HyGenius

Specifications F600 HyGenius:	
Vehicle type	Research Vehicle
Fuel cell system	PEM 66 kW
Drive	Electric motor Power (Continuous / Peak): 60 kW / 85 kW (87hp) Max. torque: 350 Nm
Fuel	Compressed Hydrogen (700 bar / 10,000 psi)
Range	>400 km (>250 miles)
Max Speed	174 km/h (109 mph)
Battery	Li-Ion, Power (Continuous / Peak): 30 kW / 55 kW (75hp) Capacity: 1.5 kWh

- 40 % smaller stack*
- Over 30 % more power*
- Up to 66 % more torque*
- Consumes equivalent of 2.9 litres of diesel per 100 km
- Can be started at temperatures as low as minus 25 °C
- Li-Ion high voltage battery implemented

*Compared to current F-Cell vehicle (based on A-Class)

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Generation 1 (Technology Demonstration) Fuel Cell Bus, 2003-2007

Specifications Fuel Cell Citaro:	
Vehicle type	Mercedes-Benz Citaro
Fuel Cell System	PEM, > 250 kW (338 hp)
Drive	Electric motor Power: 205kW (277 hp) max. torque: 1050 Nm (772 ft.-lb.)
High Voltage Grid	450 – 900 VDC
Fuel	Compressed Hydrogen (300 bar / 5,000 psi)
Range	> 200 km (124 miles)
Max Speed	80 km/h (50 mph) EU / 110 km/h (80 mph) USA
Passenger Capacity	Up to 70

Achievements

- Reliable vehicle
- Zero emissions
- Internal and external noise reduction
- High driving comfort
- New innovative drivetrain concept
- Fit for every day use

Significant improvements within 4 years

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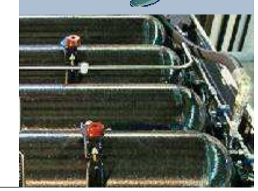
Generation 2 (Customer Acceptance)
Fuel Cell Bus FC-Hybrid, as of 2008/09

Specifications Fuel Cell Citaro:	
Vehicle type	Mercedes-Benz Citaro
Fuel Cell System	PEM, 160 kW (216 hp)
Drive	Electric hub wheel drive Power (Continuous): 2x80 kW (2x108 hp)
High Voltage Grid	450 – 750 VDC
Fuel	Compressed Hydrogen (350 bar / 5,000 psi)
Range	Target: 250 km (155 miles)
Max Speed	80 km/h (50 mph)
Battery	Li-Ion, Power (Continuous / Peak): 120 kW **/** 180 kW; Capacity: 30 Ah, 17 kWh
Passenger Capacity	Up to 75



Challenges:

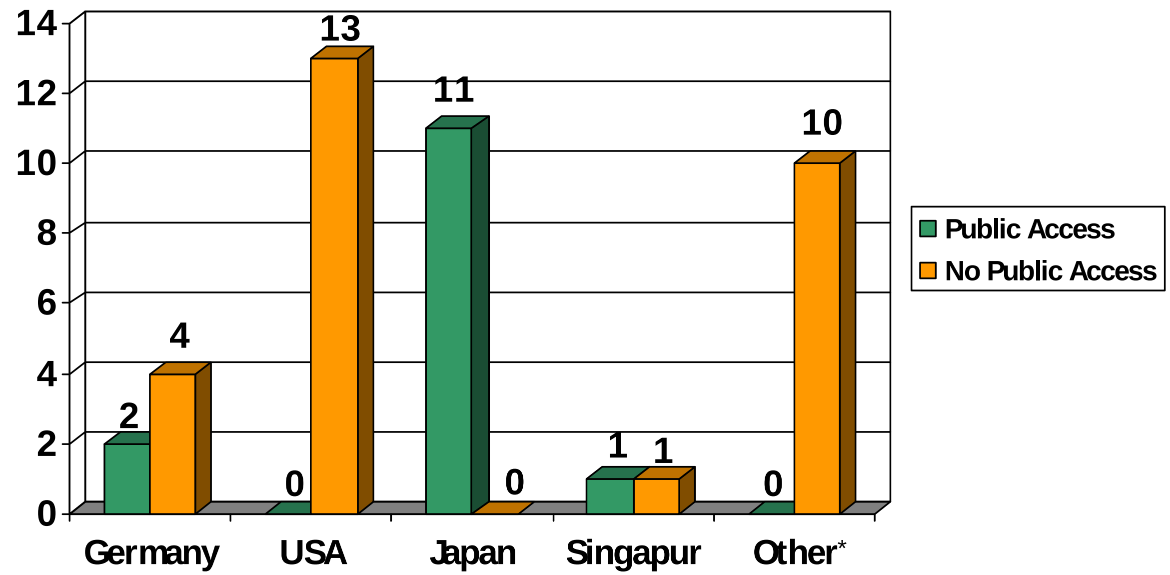
- Cost
- Reliability, lifetime
- Range
- Fuel consumption
- Hydrogen storage: 350/700 bar Technology
- Battery technology
- Freeze start
- Higher passenger capacity
- Weight reduction of power train and tank
- Noise reduction, below/in line with future legislation

Challenges for Fuel Cell Market Introduction

- Technology Challenges
  - Reduce weight
  - Reduce volume
  - Reduce complexity
  - Increase power
- Significantly reduce the component and product costs
- Manufacturer spanning standards have to be defined to ease market introduction of fuel cell vehicles
- Sales in the range of 100,000 vehicles p.a. can only be reached if the supplier can keep up with producing components in high volumes.
- Cost reduction down to the level of conventional vehicles is possible.

Fueling Stations Worldwide, Used by DaimlerChrysler

Fueling stations used by DC



DaimlerChrysler's demonstration fleet refuels at over 40 fueling stations worldwide. **Broad experiences** have been made in the last years which help to develop new technologies and allow to further improve and simplify the refueling process.
Only few fueling stations have public access. There are regional differences. In Japan every fueling station has public access, in the USA none.

* mainly for bus projects (Hyfleet CUTE; Perth; Beijing)

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Hydrogen Filling Station Requirements

- Technical requirements:
  - Adequate filling intervals
  - Hydrogen quality (communication with hydrogen producers and fuel cell manufacturers)
  - 700 bar (10,000 psi) capability

- Customer acceptance requirements:
  - User-friendly act of filling (e.g. no protective cloths necessary)
  - Fast refueling (< 3 minutes)
  - Adequate hydrogen costs (compared to conventional gasoline)
  - Sufficient network for fueling
  - Fueling stations have to be capable of refueling passenger cars and busses
  - Multi-Fuel-fueling stations in the start-up phase necessary (Gasoline, Diesel, Hydrogen)

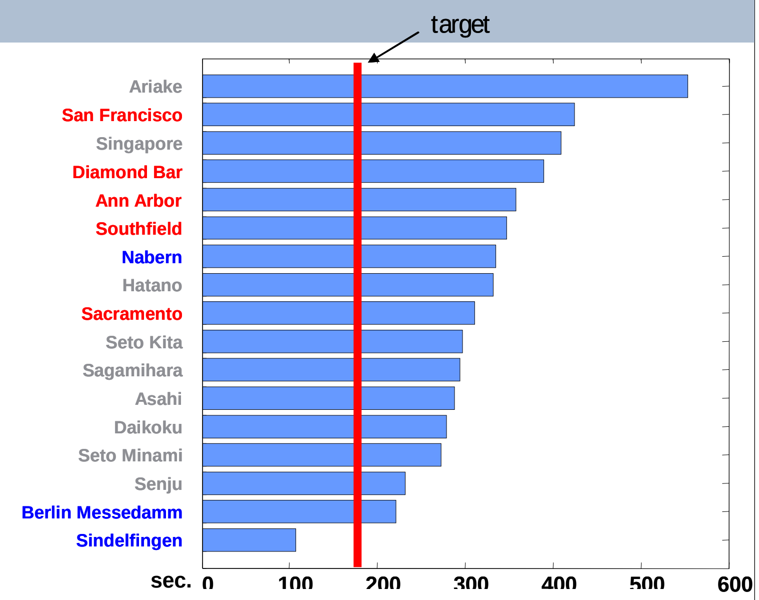
Findings by Analyzing FDA F-Cell Data

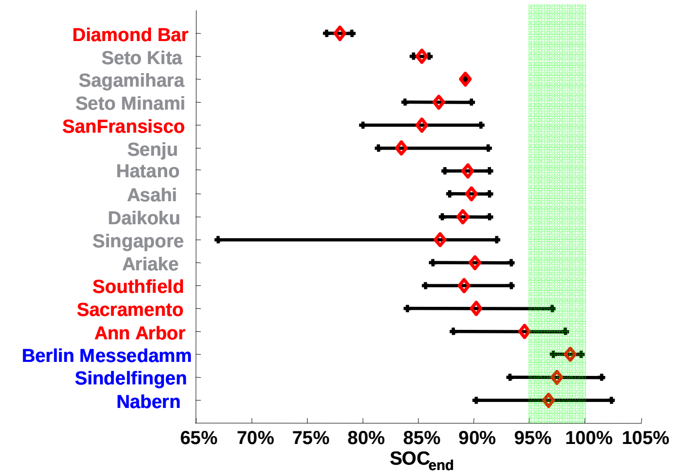
Main problems of current technology

- Duration of refueling often longer than the target value of 3 minutes
- Difficulties of reaching a complete filling (higher than 95%)

These problems can be solved by:

- *Hydrogen Precooling*:
  Refueling can be done faster, because the temperature in the vehicle storage tanks is lower than without precooling.
- *Fueling stations equipped with infrared data communication*:
  The fueling station gets the hydrogen level information from the F-Cell tank sensors. In this way a better level of filling can be achieved.





The next generation of DaimlerChrysler's Fuel Cell Vehicles has 700 bar storage technology. This is necessary to achieve adequate ranges. With regard to 700 bar technology the hydrogen precooling and infrared data communication at the fueling station gain in importance. A clear definition of interface between vehicle and station is needed.

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Conclusion

- Powertrain improvements continue to lead to cleaner and more fuel efficient vehicles.
- The two-mode hybrid system optimizes the balance of electric motors and transmission content, resulting in smaller motors, smoother operation and greater efficiency – delivering significant fuel economy improvements of up to 25 percent.
- The Sprinter PHEV program is a Technical and Market Feasibility Study evaluating the technology and customer acceptance, including the additional cost, of the plug-in feature.
- DaimlerChrysler is the technology leader in Fuel Cells
  - We have a clearly defined Fuel Cell strategy and technology roadmap.
  - Fuel Cell drivetrain costs have the potential to be reduced considerably by economies of scale, technological improvements and the installation of strategic supplier sets.
  - Cost reduction down to the level of conventional vehicles is possible.
- The build-up of hydrogen infrastructure needs to be significantly enhanced